

Workshop on Human Subjects for Biomechanical Research
Minutes of Third Annual Meeting and Technical Session

The meeting was convened by Mr. Arthur E. Hirsch, NHTSA, at 2 p.m., on Wednesday, November 19, 1975, at the Sheraton Harbor Island Hotel in San Diego, California. There were more than 55 persons in attendance. Mr. Hirsch opened by restating the purpose of the annual meetings: to bring together, for informal discussion, the researchers who are conducting biomechanical research using human cadavers. The discussions are intended to cover all aspects of testing with cadavers: instrumentation, comparability of data among different research labs, differences in measurement techniques, and the use of cadavers as surrogates. It was emphasized that the meeting is informal, with no restrictions on communications and no publications. Mr. Hirsch closed his introductory remarks by emphasizing: first, that the minutes and technical papers resulting from the meetings are not to be cited as references; and second, the fact that he chairs the meeting does not denote official DOT sponsorship of the workshop.

A brief discussion was held concerning possible official affiliation of the group with an organization such as the Society for Automotive Engineers. The consensus from those present was in favor of the present informal format. Certain participants noted problems with corporate clearance policies if individuals are identified in the minutes; these problems do not exist if they are functioning as an individual in an SAE Committee.

Dr. John Melvin, HSRI, will obtain facts about possible affiliation with SAE and other alternative organizations and will present his findings to the group in 1976.

A new name for the meeting was adopted. Henceforth, it will be known as the Workshop on Human Subjects for Biomechanical Research.

COMMITTEE REPORTS:

1. Ad-hoc Committee on Guidelines for the Comparison of Human and Human Analogue Biomechanical Data. Dr. Daniel J. Thomas (NAMRL), Chairman distributed copies of the committee's second annual report. The report contains two recommendations and notes three problem areas. The first recommendation is a sixth guideline for comparisons of mechanical data. This involves the establishment of anatomical coordinate systems for isolated segments so that they align with each other as much as possible when the standard anatomical position is established. The second recommendation is for the establishment of a pelvic coordinate system based on the triangle formed by the right and left anterior superior iliac spines and the most superior point of the pubic symphysis.

The three problems cited include localization of anatomical points for definition of coordinate systems, anthropometry of cadavers to define coordinate axes related to dynamic properties, and the concept of comparability (not just of data) between humans and human analogues. The Ad-hoc Committee's report is attached to these minutes and contains more details about the recommended axis system locations and the problems noted in committee discussions.

Dr. Thomas concluded his report to the workshop by noting that the committee will remain ad-hoc and will continue to meet. They anticipate discussing the problems of the hand and the deformable thorax, comparability of instrumentation, and anthropometry, and will report to the 1976 meeting.

2. Ad-hoc Committee on Detailed Injury Scaling and Cadaver Characterization

Dr. John Melvin, HSRI, and Dr. Claude Tarriere, Peugeot-Renault, are co-chairmen of this committee. Dr. Melvin presented the first portion of the report which dealt with calibration of cadavers, particularly mechanical characterization. A simple test that could be conducted easily by all investigators and reported as part of their data would be highly desirable. The committee suggested a three-point bending test of a rib as a potentially useful comparison, and cited work by Granik and Stein which describes the test and gives data from 80 subjects. The committee also addressed cadaver anthropometry, suggesting that a core group of measurements be taken on all cadavers to establish a basis for comparisons of size and dynamic properties. (This subject is addressed in more detail in the committee report by Dr. Reynolds). Dr. Melvin requested that investigators obtain a group of measurements from cadavers they test during the coming year, so the workshop can have a data base for discussion at the next meeting.

The committee also addressed an injury scaling technique to report cadaver injuries. The AMA/SAE/AAAM Committee revising the Abbreviated Injury Scale (AIS) had been consulted, and Dr. Melvin suggested that cadaver test results should be expressed in AIS ratings so that they may be compared to field investigations. He concluded by stating that next year's committee report will deal with details rather than "philosophy."

Dr. Tarriere then presented a proposal for a detailed injury rating system; his report is included with the minutes. Among the suggested features of the system are an increased number of body regions (for example, head and neck should be considered separately), a definition of what portions of the body should be included in the various regions (is the clavicle part of the thorax or part of the upper limb?), and a method of representing various levels of

injury scaling (injury ratings should be assigned to detailed subgroupings first, then combined for body regions and whole-body summaries). He also pointed out that less serious injury should not be neglected by assigning only the highest severity for the entire region.

Dr. Tarriere's report also included a proposal for a Thoracic Cage Severity Index (TCSI), with five severity categories for increasing damage from a single rib fracture to severe flailed chest.

Discussion after the report centered on the precise definitions necessary to assign thoracic injury levels. Dr. Tarriere said the distinction is one of thorax displacement and mobility. Another participant noted possible international differences in medical terminology that might assign different degrees of severity to the same injury. The need for correlation between energy levels to the thorax and threat to life was also noted.

Dr. Tarriere concluded with the request that research teams apply the proposed levels for a year, so that problems in application of the criteria could be discussed at the next workshop.

3. Ad-hoc Committee on Cadaver Anthropometry. Dr. H.M. Reynolds, HSRI, presented the first report of this new ad-hoc committee, which grew out of discussion in Dr. Thomas' guidelines committee. Dr. Reynolds described the basic problem as one of obtaining sufficient related measures to describe a body in three-dimensional space. Working with other researchers in the field, he has compiled a list of proposed anthropometric measurements for cadavers. The measures and their definitions are contained in the committee report which is included with these minutes.

4. Ad-hoc Committee on a Statement of Ethics. The report by committee chairman Dr. R.G. Snyder, HSRI, was presented by D.R. Foust, HSRI. A "Resolution concerning ethical position on the use of human bodies in research" has been

adopted by the American Association of Physical Anthropologists.

It described a group of principles to which researcher using human remains are encouraged to subscribe, and requests the National Academy of Sciences National Research Board to recommend their use. The resolution was read to the group, with the comment that it would now be appropriate to cite compliance with the principles when reporting the results of experiments with cadavers. With the adoption of the resolution, the committee's work was completed and the committee is dissolved.

TECHNICAL SESSION

The committee reports being completed, Mr. Hirsch then moved into the technical session. Thirteen brief, informal presentations were made, dealing with instrumentation standards and techniques, cadaver characterization, and testing techniques. This section of the minutes includes a brief description of each presentation.

1. Interim Progress Report on Mouth-Contained Accelerometer Transmitter, E.F. Konigsberg, Konigsberg Instruments Inc. Mr. Konigsberg described a miniaturized nine-accelerometer, 10-transmitter mouth-located instrument package that is intended to fit inside a boxer's mouthpiece. The first prototype is expected to be complete by May 1, 1976, with an additional two ready by June 30, 1976. Pertinent design specifications include a frequency response of 0.1 Hz - 500 Hz, power requirement of nine milliwatts, 10 mv output, 1/10% resolution. It will weigh 150 g, operate for 20 minutes (with present batteries) with a range of 20 feet, and will sample at a rate of 1250/sec. The receiver is connected to a microprocessor which compensates for pre-test baseline zero, and channel mixing from the nine miniature linear accelerometers will be accomplished after transmission.

In response to questions, Mr. Konigsberg stated that the distance between accelerometers will be between 1/2 and 3/4 inches, a 1250/sec sampling rate is used to obtain good filtering characteristics for a 500 Hz bandwidth, and the 500 Hz bandwidth was required because of natural filtering characteristics of the necessarily non-rigid mouthpiece. He noted that the accelerometers will pass 1000 Hz and the receiver will work at the 500 Hz level. The nine accelerometers are arranged in the manner suggested by Dr. King of Wayne State.

2. Experience with Proposed Pelvic Coordinate System, A.J. Padgaonkar, Wayne State University. An experiment was conducted to assess the practical application of the pelvic coordinate system as proposed by the Ad-hoc Committee on Guidelines. A segmented cadaver was placed in a locator box and held in a consistent position. X-rays were taken at 90° to each other, and the anterior superior iliac spines and pubic tubercles were successfully located in A-P, S-I, and lateral views. The primary difficulties encountered were with parallax of the X-ray source and linearity errors; the film cassette must be aligned very carefully. Some discussion of using the orthogonal photogrammetry technique followed, with the observation that position of the pelvis relative to the desired anatomic plane is not too critical so long as the 3-D geometry is understood and the pictures are orthogonal.

3. Mathematical Instability in the Use of Six Linear Accelerometers to Determine Three-Dimensional Angular Acceleration, Dr. Y.K. Liu, Tulane University. Dr. Liu briefly reviewed a discussion from the 1974 meeting in which problems associated with integrating linear acceleration results to obtain three-dimensional angular accelerations were presented. (An algebraic solution to obtain angular acceleration was possible if nine accelerometers were used). Dr. Liu applied an analytical approach using the stability-analysis technique devised by

Routh and Hurwitz in 1892. The technique, in which a slight perturbation is applied to a stable linear system, results in an algebraic solution to an equation matrix. When this method is applied to the six-accelerometer problem, a critical term is missing after the matrix is solved, and thus the system is inherently unstable. Dr. Liu drew several conclusions from this analysis, pointing out that the six-accelerometer technique cannot be made stable and, if used at all, must be used very carefully.

4. Conditions under which a Six-Accelerometer System may be used to Calculate Angular Acceleration, Dr. N.M. Alem, Highway Safety Research Institute.

Dr. Alem agreed with Dr. Liu that the six-accelerometer system is mathematically unstable, but maintained that in limited application the instabilities do not become overwhelming until after the desired important data are obtained. The condition specifically mentioned was impact to the skull of a high -g, short-duration nature. During the initial phase of the event an adequate solution for angular acceleration has been obtained using six linear accelerometers. This solution was supported by both experimental and mathematical validation; for several durations and several impacts, errors generated during solution were within acceptable limits. Dr. Alem did, however, recommend a nine-accelerometer system for new applications or where a system is to be universally applicable.

Captain C.L. Ewing, Naval Aeromedical Research Laboratory, then commented on NAMRL's experience with the six-accelerometer system that they use in head-neck response testing. He noted that valid data may be obtained for 165-175 msec into the test, and since an accelerator sled is used, that amount of time is sufficient. He also cited some of the practical considerations that make it difficult to use a nine accelerometer system in tests with living

humans (available data channels, weight minimization, etc.). NAMRL also has backup capability to calculate angular acceleration from high-speed motion pictures if accelerometer data are suspect.

Another question was posed about the state of development of an angular accelerometer. It was noted that the Endevco 7301 is an angular accelerometer that is on the market. An Endevco representative described it as a single-axis device with three sensors inside (not linear accelerometers) to cancel linear accelerations. However, the device may be too large for many human testing applications.

5. A Calibration for Rotational Acceleration, Dr. R.H. Eppinger, NHTSA.

Dr. Eppinger discussed the development of a device that could use other measurements to generate angular acceleration without actually measuring angular velocity. A set of equations were used that related a rate table and an instrumentation platform. A method has been devised whereby amplitude and frequency calibration checks may be conducted without measuring an angular acceleration.

6. Status Report-Chest Deflection Measurement Using Ultrasound, H. Peel, Southwest Research Institute. Mr. Peel discussed the development of a deflectometer which has now been built and is under test with both fresh and embalmed cadaver. The deflectometer is a pitch-catch system in which the transmitter is located on the Xiphoid process of the sternum and receivers are mounted on either side of the spine (connected in parallel). As the chest deflects, the amount of deflection is measured from changes in the ultrasound signal. Several problems were noted in dynamic testing. These deal with maintaining power levels to the transmitter, the effects of motion on the received signal (especially with unembalmed cadavers), and a sensitivity to temperature changes that requires calibration to each subject. He noted that SWRI has found significant differences

in instrument behavior in tests among live, fresh, freshly-embalmed, and long-embalmed subjects. Transmitter excitation required is 5v for live tissues, 25-30v for fresh cadavers, 50-60v for freshly-embalmed, and impractical for long-embalmed tissues (cannot transmit effectively because the sound is dispersed by shrunken tissues). In response to a question regarding preferred paths of transmission through the body, Mr. Peel said transmission is not good through bone, since bone reflects most of the sound. It would be impractical to place the transmitter high on the sternum or receivers on the spine. Also responding to questions, Mr. Peel noted that (1) different tissues propagate sound at different speeds, so the deflectometer responds only to the leading edge of the signal, and (2) multiple pairs of transmitters and receivers could be used to detect multiple deflections by using different frequencies, but their development is a "long way off."

7. Inductive Coil Chest Deflectometer, M. Walsh, Calspan Corporation. A different technique of measuring chest deflection was discussed by Mr. Walsh. The Calspan device measures deflection with a 10 K Hz inductive coil transmitter and receiver, displacement being a function of signal coupling. He reported that the coil is hard-potted to the chest. While they still have some problems with belt-loading artifacts since angular displacement of the coil can affect the reading, there have been good results with the most recent two subjects. Deflection has correlated well with arterial pressure, lung pressure (they pressurize the arterial system and lungs of a cadaver with a jellied substance), and belt loads. On the basis of their testing to date, Mr. Peel feels that mapping of pressure regions is a better indicator of thoracic cage injury than point measurement of deflection.

8. Instrumentation of the Chest for Desired Kinematic Response Measurements, Dr. D.H. Robbins, Highway Safety Research Institute. Dr. Robbins reported

on a newly-developed instrumentation system that uses ten accelerometers to record the response of a cadaver chest in an impact test. Location of the accelerometers is standardized (biaxials on T1 and T2, single-axis on the 4th and 8th ribs-- both right and left lateral aspect--and top and bottom of sternum). The objective of the program is to correlate accelerations with actual injuries and to use statistical models to predict AIS within $\pm 1/2$ unit. A major problem has been establishing the three-dimensional location of the accelerometers relative to a good thoracic anatomic landmarks. To date, the location has been fixed relative to the NAMRL T-1 coordinate system with the cadaver supine. The next step is to make similar measurements with the cadaver in sitting position. Dr. Robbins has been "very concerned" about effects of instrumentation placement on torso integrity. He believes that the rib mounts cause no trauma, but is not yet "100% certain" about the spinal mounts. Another problem is that the data base for comparison with AIS is very small and will grow too slowly unless other researchers use similar techniques.

9. Normalization of Cadavers. Professor L.M. Patrick, Wayne State University. Professor Patrick has observed great differences in pulse shape and duration for similar test conditions and feels that some of these disparities are due to differences in cadaver characteristics. He proposed a standardized "Normalization" test to compare cadaver--specifically a crush test of the first lumbar vertebral body. Test results, if correlated to factors like age, size and length of time confined to bed, might provide some means of factoring out test differences due to cadaver condition.

Before introducing the next speaker, Mr. Hirsch mentioned that Dr. Orne, (Wayne State), had given him an abstract concerning a non-destructive rib test which could be used to preselect cadavers for thoracic-impact testing. The abstract is included with these minutes.

10. A Technique for Rib Characterization, Dr. R.H. Eppinger, NHTSA. Dr. Eppinger discussed in more detail the rib three-point bending test that had been mentioned by Dr. Melvin in his committee report. This bending test was reported by Granik and Stein in the Journal of Biomechanics (Vol. 6, No. 3, May 1973, p. 237). The test consists of excising a six-inch section of the 6th or 7th rib, at the point of least curvature. A four-inch span is loaded at mid-span at the rate of 0.1 inch/minute until fracture. Force characteristics are recorded, and moment of inertia and cancellous-bone cross-sectional area are inferred from Ultraviolet photographs. From these, a rupture modulus of the rib is calculated. Granik and Stein reported on 80 subjects thus tested and concluded that a reduction of 4-5:1 in rupture modulus could be expected between specimens obtained from accidental-death victims and those from long-bedridden patients. Dr. Eppinger has conferred with the authors and feels that the test would be a simple post-test procedure. He recommended that it be performed by all investigators.

Dr. Melvin commented that he has tried the technique, but had difficulty obtaining rib sections post-test that are long or flat enough. Response to another question indicated that both rupture load and rupture modulus are important quantities to determine. Questions regarding the testing technique resulted in recommendations to test as soon as possible after an

experiment to reduce time effects, to test with a constant-loading device (though fracture loads are generally less than 100 lbs), and to test with rib curvature up, since that corresponds to the method by which the published data base was obtained.

11. Pressurization of the Vascular System, H. Peel, Southwest Research Institute. Mr. Peel abstracted a paper due to be presented at the 19th AAAM meeting later in the week, which discusses the problems encountered in trying to simulate arterial pressure in cadaver thoracic impact tests. SWRI uses a combination of distended balloons and polyethylene beads. The balloons are placed at diaphragm level to prevent loss in tests requiring only supra-diaphragm pressurization. The beads are 4-50 microns in diameter and plug the capillaries. The method has been effectively used in four cadavers to maintain pressures of 80-120mm of mercury with only 1000 cc of saline solution and with no edema.

12. Rib Testing and Bone Mineralization, Dr. C.H. Tarriere and A. Fayon, Peugeot-Renault. Dr. Tarriere described a recent test program in which rib sections were tested to determine the mineral salts content and the material properties of static and dynamic shear and bending. Mineral salts are measured as a percentage of bone in the rib cross-section area. Dr. Fayon then discussed the material properties tests. A short span of flat rib is used (a long span is difficult to obtain post-test). Standard techniques are used for static bending and shear tests; the dynamic test is a falling mass which impacts the rib beam. Preliminary results indicate good correlations between shear and age, shear and mineral salts percentage, and shear and rib thickness. However bending test results have not yielded as good correlations.

13. High-speed X-ray Device, Dr. J.W. Melvin, Highway Safety Research Institute. Dr. Melvin described a new method being developed to take X-rays on high-speed motion picture film. The system is very flexible; it is completely uncoupled in that it can use any X-ray constant potential source and any size fluorescent screen. A four-stage tube image intensifier is used and a normal high-speed camera takes the pictures. The device is not yet optimized for the contrast medium, but has been successfully tested and is nearly ready to generate data. It will initially be capable of film speeds to 1000 frames/second and ultimately will accept 3000 frames/second.

With the end of the Technical Session, the Workshop came to a close. It was agreed that the Fourth Annual Workshop would be held following the 20th Stapp Conference at the Hyatt Regency Hotel in Dearborn, Michigan. The meeting was adjourned by Mr. Hirsch at 6:00 p.m.

David R. Foust, HSRI
Recorder

